

**61140, 61160 and 61180**  
**Soils**  
 229, 153 and 271 grams

*DRAFT*



Figure 1: Apollo 16 commander taking picture of 61135 before collecting 61181. AS16-109-17800.

### Introduction

61140, 61160 and 61180 were part of radial sample collected at Plum Crater, Apollo 16. 61180 was collected from beneath rock sample 61135 on the rim of Plum Crater (Sutton 1981). Plum Crater is on the rim of a large crater (Flag Crater, 200 m across, ~40 m deep) that, according to pre-mission planning, should

have penetrated the regolith and sampled the underlying Cayley Formation (Head 1974). 61140 was collected about 30 m from the crater rim. However, these samples do not appear to have been studied together as a suite; different samples were allocated to different investigators. Perhaps this is because there are several

#### **Modal content of soils 61161 (90-150 micron).**

	<b>Heiken et al. 1973</b>	<b>Houck 1982</b>
Agglutinates	37 %	35.4
Basalt	0.3	0.3
Breccia	33.3	27.8
Anorthosite	4.7	1.4
Norite	-	
Gabbro	0.9	
Plagioclase	14.7	21.7
Pyroxene	2.6	2.5
Olivine	-	
Ilmenite	-	
Glass other	4.1	7.2

#### **Modal content of soils 61181 (90-150 micron).**

	<b>Heiken et al. 1973</b>	<b>Houck 1982</b>
Agglutinates	59.6 %	56
Basalt	0.6	2.9
Breccia	25.9	27.8
Anorthosite	4.3	0.7
Norite	-	
Gabbro	0.9	
Plagioclase	6.9	10.5
Pyroxene	0.9	0.3
Olivine	-	
Ilmenite	-	
Glass other	0.6	4

craters in the area and a radial sample didn't quite make sense here.

### Petrography

61161 and 61181 are surface soils with high maturity ( $Is/FeO = 82$ ) and an abundance of agglutinates. For some reason, 61141 apparently has lower maturity ( $Is/FeO = 56$ ) (Morris 1978). The mineralogical mode was determined by Houck (1982) and Heiken et al. (1973). Butler et al. (1973) reported the grain size distribution for 61141.

Keller and McKay (1992) studied vapor deposits on grains in 61181 as part of their investigation of "space weathering". They found that the ultra-fine (<20 micron) fraction contained numerous tiny glass spheres with either refractory composition (HASP) or volatile-rich (VRAP). HASP stands for high alumina silica poor; VRAP stands for volatile-rich alumina-poor. They are apparently complementary material derived by high-temperature volatilization and re-condensation during impact into feldspathic highland rocks (figure 5).

### Chemistry

Eldridge et al. (1973) and Wrigley (1973) reported the U, Th and K content of bulk samples, in general agreement with trace element analysis of sample splits (Rose et al. 1973, Wanke et al. 1973, Taylor et al. 1973 and Korotev 1982).

Kerridge et al. (1978) and Becker (1980) reported 98, 111 and 116 ppm C and 59 - 73 ppm N for 61141 and 61161 (figure 3). C and N are closely correlated, indicating that they are both from solar wind implantation. Kerridge et al. (1975) reported 330 ppm S in 61141 and 470 ppm S in 61161. Cirlin and Housley (1981) reported excess, surface-correlated, Cd and Pb in 61161.

### Cosmogenic isotopes and exposure ages

The cosmic-ray-induced activity of 61181 is  $^{22}\text{Na} = 40$  dpm/kg and  $^{26}\text{Al} = 204$  dpm/kg (Eldridge et al. 1973). The activity of 61161 is  $^{22}\text{Na} = 65$  dpm/kg and  $^{26}\text{Al} = 202$  dpm/kg (Wrigley 1973).

Behrmann et al. (1973) and Bhattacharya et al. (1975) studied the cosmic-ray tracks in grains from 61181.

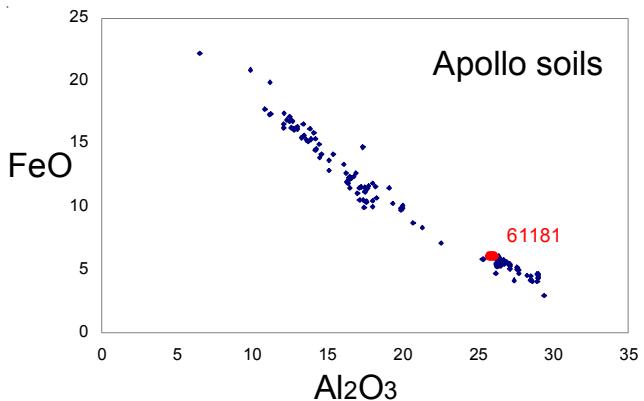


Figure 2: Chemical composition of lunar soils including 61181 (see table).

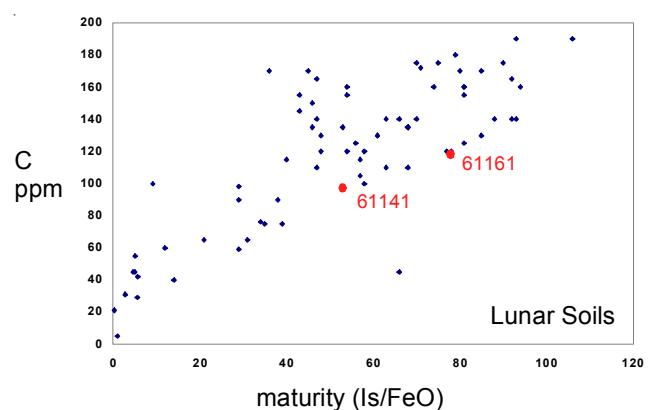


Figure 3: Carbon content and maturity index for 61141 and 61161 (Kerridge et al. 1978, Morris 1976).

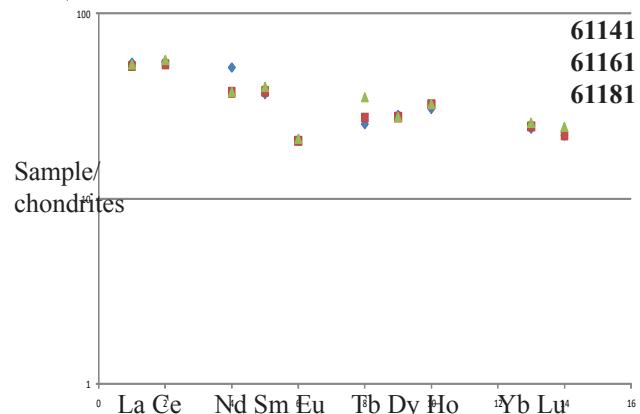


Figure 4: Normalized rare-earth-element diagram for 61141, 61161 and 61181 (data from tables).

## Other Studies

The rare gas content of 61181 was reported by Kirsten et al. (1973) and Walton et al. (1973). It has high Ne content.

Several investigators studied the magnetic properties (Tsay et al. 1973, Weeks 1973, Griscom et al. 1973).

Isotopic ratios for N and C were determined by Kerridge et al. (1978) and Becker (1980).

## Processing

Marvin (1972) documented the coarse fine particles.

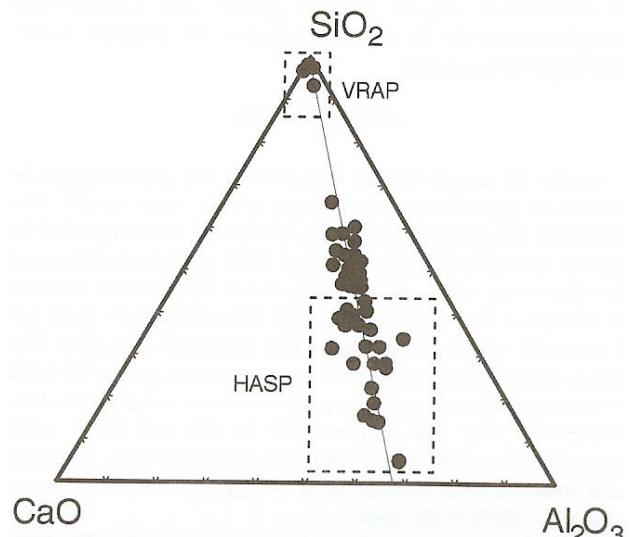
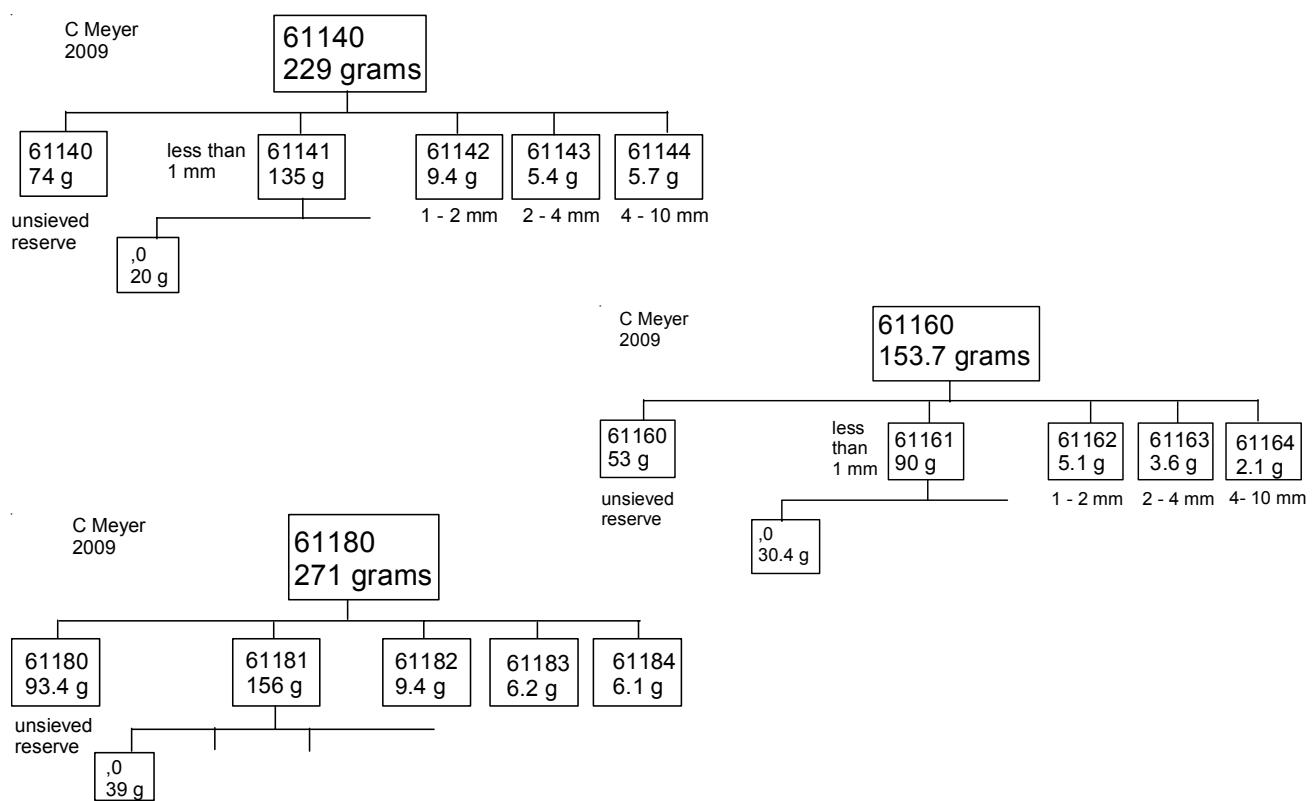


Figure 5: Chemical composition of glass condensates (VRAP) and refractory residual (HASP) in 61181 (Keller and McKay 1992).



**Table 1. Chemical composition of 61141.**

reference	Rose73	Wanke73	Evenson73
<i>weight</i>			
SiO <sub>2</sub> %	45.2	(a) 44.9	(b)
TiO <sub>2</sub>	0.58	(a) 0.53	(b)
Al <sub>2</sub> O <sub>3</sub>	26.4	(a) 26.5	(b)
FeO	5.29	(a) 5.33	(b)
MnO	0.07	(a) 0.06	(b)
MgO	6.1	(a) 6.2	(b)
CaO	15.32	(a) 15.1	(b)
Na <sub>2</sub> O	0.52	(a) 0.45	(b)
K <sub>2</sub> O	0.14	(a) 0.11	(b) 0.11 (c)
P <sub>2</sub> O <sub>5</sub>	0.12	(a)	
S %			
<i>sum</i>			
Sc ppm	9.5	(a) 8.4	(b)
V	20	(a)	
Cr	890	(a) 660	(b)
Co	19	(a) 24.4	(b)
Ni	310	(a) 400	(b)
Cu	11	(a)	
Zn	28	(a)	
Ga	4.3	(a)	
Ge ppb			
As			
Se			
Rb	2.8	(a)	2.55 (c)
Sr	165	(a) 140	(b) 170 (c)
Y	39	(a) 38	(b)
Zr	126	(a) 167	(b)
Nb		11	(b)
Mo			
Ru			
Rh			
Pd ppb			
Ag ppb			
Cd ppb			
In ppb			
Sn ppb			
Sb ppb			
Te ppb			
Cs ppm			
Ba		110 (b)	122 (c)
La		12.7 (b)	
Ce		33 (b)	
Pr			
Nd		23 (b)	
Sm		5.4 (b)	
Eu		1.17 (b)	
Gd			
Tb		0.92 (b)	
Dy		6.9 (b)	
Ho		1.7 (b)	
Er			
Tm			
Yb	2.6	(a) 3.9	(b)
Lu		0.53 (b)	
Hf		4 (b)	
Ta		0.42 (b)	
W ppb			
Re ppb			
Os ppb			
Ir ppb		12 (b)	
Pt ppb			
Au ppb		10 (b)	
Th ppm		1.7 (b)	
U ppm			

technique: (a) "microchemical", (b) INAA, (c) IDMS

**Table 2. Chemical composition of 61161.**

reference	Eldridge73	Wanke73	Wrigley73
<i>weight</i>			
SiO <sub>2</sub> %		44.7 (a)	
TiO <sub>2</sub>		0.58 (a)	
Al <sub>2</sub> O <sub>3</sub>		26.3 (a)	
FeO		5.65 (a)	
MnO		0.065 (a)	
MgO		6.35 (a)	
CaO		15.9 (a)	
Na <sub>2</sub> O		0.47 (a)	
K <sub>2</sub> O	0.1	(b) 0.1 (a)	0.11 (b)
P <sub>2</sub> O <sub>5</sub>		0.12 (a)	
S %			
<i>sum</i>			
Sc ppm		8.7 (a)	
V			
Cr		670 (a)	
Co		29 (a)	
Ni		400 (a)	
Cu			
Zn			
Ga			
Ge ppb			
As			
Se			
Rb			
Sr		150 (a)	
Y		37 (a)	
Zr		184 (a)	
Nb		11.5 (a)	
Mo			
Ru			
Rh			
Pd ppb			
Ag ppb			
Cd ppb			
In ppb			
Sn ppb			
Sb ppb			
Te ppb			
Cs ppm			
Ba		120 (a)	
La		12.2 (a)	
Ce		32 (a)	
Pr			
Nd		17 (a)	
Sm		5.6 (a)	
Eu		1.15 (a)	
Gd			
Tb		1 (a)	
Dy		6.7 (a)	
Ho		1.8 (a)	
Er			
Tm			
Yb		4 (a)	
Lu		0.54 (a)	
Hf		3.8 (a)	
Ta		0.52 (a)	
W ppb			
Re ppb			
Os ppb			
Ir ppb		19 (a)	
Pt ppb			
Au ppb		13 (a)	
Th ppm	1.97	(b) 1.5 (a)	1.97 (b)
U ppm	0.55	(b) 0.54 (b)	
technique: (a) INAA, (b) radiation counting			

**Table 3. Chemical composition of 61181.**

reference Eldridge73 Taylor73 Korotev82

*weight*

SiO <sub>2</sub> %	44.6	(b)	
TiO <sub>2</sub>	0.66	(b)	
Al <sub>2</sub> O <sub>3</sub>	27.1	(b)	25.2 (c )
FeO	5.47	(b)	5.54 (c )
MnO			0.069 (c )
MgO	5.78	(b)	5.9 (c )
CaO	15.56	(b)	14.4 (c )
Na <sub>2</sub> O	0.51	(b)	0.463 (c )
K <sub>2</sub> O	0.11	(a)	0.25 (b)
P <sub>2</sub> O <sub>5</sub>			0.18 (b)

S %

*sum*

Sc ppm	12	(b)	9.26 (c )
V	29	(b)	21 (c )
Cr	850	(b)	760 (c )
Co	27	(b)	31.5 (c )
Ni	340	(b)	435 (c )
Cu	8.5	(b)	

Zn

Ga

Ge ppb

As

Se

Rb

Sr			180 (c )
Y	44	(b)	
Zr	197	(b)	185 (c )
Nb	13.7	(b)	

Mo

Ru

Rh

Pd ppb

Ag ppb

Cd ppb

In ppb

Sn ppb 0.11 (b)

Sb ppb

Te ppb

Cs ppm		0.18	(c )
Ba		139	(c )
La	13.9	(b)	12.43 (c )
Ce	38.5	(b)	33.9 (c )
Pr	5.6	(b)	
Nd	22.1	(b)	
Sm	6.05	(b)	5.92 (c )
Eu	1.51	(b)	1.185 (c )
Gd	7.77	(b)	
Tb	1.15	(b)	1.28 (c )
Dy	7.63	(b)	
Ho	1.79	(b)	
Er	4	(b)	
Tm	0.79	(b)	
Yb	4.76	(b)	4.17 (c )
Lu	0.74	(b)	0.593 (c )
Hf	3.9	(b)	0.654 (c )

Ta

W ppb

Re ppb

Os ppb

Ir ppb 15.9

Pt ppb

Au ppb

Th ppm 2.02 (a) 2.12 (b) 2.09 (c )

U ppm 0.56 (a) 0.55 (b) 0.54 (c )

technique: (a) radiation counting, (b) spark source mass spec., (c) INAA

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